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a hole in the arch of the cupola, the latter having a thickness of one foot and the hole being two inches in diameter. A sheet of paper, upon which a circle was drawn, was placed exactly under the point of the pendulum. As the hourly deviation for Aarhus (56° north latitude) amounts to very nearly 12°, two principal radii were drawn, forming an angle of 12° with each other. The radii were extended by means of chalk lines to a length of 57 inches, so that every degree of the circumference was just one inch long. Two burning candles were placed outside of the circle, in the prolongation of the radii, in order to show the deviation of the pendulum more distinctly. At the beginning of the experiment the point of the pendulum also passed through two layers of sand, placed on opposite sides of the circle.

As the thread was burned and the pendulum began to move, the organ commenced to intone and the audience of 200 people followed, with the greatest attention, the slow turning of the ground in reference to the undeviating plane of oscillation of the pendulum.

The pendulum made 13 oscillations in a minute, and when it had completed 65 oscillations its point showed exactly the calculated deviation of 1° towards the west. After an hour had elapsed the pendulum had just passed the 12th degree of the circle. Later on trials were made to ascertain what influence side currents of air would have on the movement of the pendulum, but although large plates were swung close to the pendulum, no effect upon the same could be detected. As it was also important to determine the value of the inertia, experiments were made with the gyroscope for that purpose.

THE RUTHERFURD PHOTOGRAPHIC MEASURES OF THE *PLEIADES.*

By Dr. W. L. Elkin,
Astronomer of the Observatory of Yale University.

The publication of the large collection of material contained in the Rutherfurd photographic plates, of whose value there can hardly now be two opinions, has been commenced by the Columbia College Observatory, and in an interesting paper (*Contributions from the Observatory of Columbia College*, No. 3), Mr. HAROLD JACOBY has given us an account of the deductions of the results from ten plates of the *Pleiades* taken in 1872 and 1874.

The details of the measuring apparatus and the methods of measurement are to form a subsequent paper by Prof. REES, but starting from the measured distances and position-angles from a central star, Mr. JACOBY has applied all the apparently requisite corrections and deduced the relative places of 75 stars for the epoch 1873.0.

These corrections are briefly: (1) the division errors of the glass scales, which were determined by Prof. W. A. ROGERS; (2) the run of the micrometer-screw which gave the fine subdivision of the scale; (3) the correction for refraction, for which Mr. JACOBY has deduced very complete formulae for the case in which the data are the true distance and position-angle at the central star; and (4) the corrections for precession, nutation and aberration.

The scale-value was determined for each of the two impressions (exposures) on each plate by a comparison of the distances of six suitable stars from the central star with values found from the Königsberg and Yale measurements. While this process is probably sufficiently accurate, it is by no means exhaustive and it would have been of considerable interest to have compared *all* the measured distances with the heliometer values, and collated them with regard to possible effect of varying magnitude, distance and direction.

The position-angle zero was determined by means of an impression of the central star made after the star had been allowed to trail nearly off the plate. This is theoretically sound, but in practice it would seem difficult to prove that the telescope might not have slightly changed in declination in stopping and re-starting the clockwork.

Each plate was reduced with its own scale-value and position-angle zero, and no systematic corrections are applied to reduce to the mean result of all the plates. Mr. JACOBY shows, as is, however, almost self-evident, that if *all* the stars are measured on *all* the plates, the effect of such correction is finally, *nil.* This is very nearly the case for the series of plates in question and probably very slight changes would have been caused by applying this process.

The values for the reduced distances and position-angles for the several impressions, for the larger part of the stars, twenty in number, show a close accordance and the average probable error of a distance-result was about ±0″.18, and that of a position-angle result about ±0″.27; this latter value being probably greater, as Mr. JACOBY remarks, on account of the more absolute character of the angles. An inspection of the tabulated values fails to reveal any larger discordances, such as might be attributed to distortion of the film, and there seems to be but one residual exceeding 1″, for the distances, at least, except in the case of the last star (No. 75), which must have fallen very close to the edge of the plate. As every measure made has been utilized, this is very eloquent testimony to the stability of the albumen-collodion film and to the care taken in the manipulation of the plates.

The final test of the accuracy of the photographic results must lie in the comparison with those of other methods, whose accuracy can be estimated, and thus the comparison which Mr. JACOBY gives of the final concluded values with those of the heliometer is of especial interest.

Mr. JACOBY gives the differences of the photographic co-ordinates from values interpolated from the Königsberg and Yale measurements but does not deduce any criterion of accuracy beyond remarking that the photographic results agree quite as well with those of the heliometer as the two triangulations made at Yale agree *inter se.* This is quite true, but as the *differences* of the two Yale measurements are subject to probable errors of from 0″.15 to 0″.27, according to the magnitude of the stars, it is a little misleading as to the value of the photographic results, for which the residuals are given from what is very nearly the mean result of the Königsberg and the two Yale triangulations and are thus not far from expressing the accuracy of the photographic co-ordinates alone. I have thought it of some interest to compute the probable errors of the photographic co-ordinates from these residuals using the values derived in my *Pleiades* paper as to the accuracy of the heliometer results.

If ϵ_1 and ϵ_2 are the probable errors of a co-ordinate given by two measurements at the epochs t_1 and t_2, the probable error ϵ of a value interpolated for any epoch t may be derived from the expression

$$\epsilon^2 = \epsilon_0^2 + (\epsilon_1^2 + \epsilon_2^2)\left(\frac{t - t_0}{t_2 - t_1}\right)^2,$$

when

$$\epsilon_0^2 = \frac{\epsilon_1^2\,\epsilon_2^2}{\epsilon_1^2 + \epsilon_2^2} \text{ and } t_0 = \frac{t_1\epsilon_2^2 + t_2\epsilon_1^2}{\epsilon_1^2 + \epsilon_2^2}.$$

Adopting the values $\pm 0''.07$ and $\pm 0''.14$ for the two classes of the Königsberg work, and those on page 86 of my *Pleiades* paper for the second magnitude classes, we get the following table:—

Magnitude.	P. error of Königsberg Co-ordinates.	P. error of Yale Co-ordinates.	ϵ_0^2	t_0	ϵ for t = 1873.
	″	″			″
3.0 to 7.5	±0.07	±0.075	0.00262	1861.0	0.058
" "	0.14	0.075	437	1875.0	.066
7.6 8.1	0.14	0 080	483	1873.9	.070
8.2 8.8	0.14	0.099	652	1870.0	.081
8.9 9.2	0.14	0.135	944	1863.3	.106

The probable value of a residual $\Delta\alpha \cos\delta$ or $\Delta\delta$ as given by Mr. JACOBY I find to be for the several classes as follows, adding the probable error of a heliometer co-ordinate as just deduced and finally the probable error of a photographic co-ordinate as found from combining the two sets of values:—

Magnitude.	Prob. Residual.	Prob. Error of Hel. Co-ordinates.	Prob. Error of Photo. Co-ordinates.	No. of Stars.
	″	″	″	
3.0 to 7.5	±0.150	±0.058	±0.139	10
" "	152	0.066	.137	9
7.6 8.1	163	0.070	.147	14
8.2 8.8	186	0.082	.167	10
8.9 9.2	148	0.106	.103	5

Thus in the mean the photographic co-ordinates from the ten plates appear to be affected with a probable error of about $\pm 0''.14$. The accuracy of the heliometer values, for the bright stars, at least, has certainly not been over-estimated (see, for instance, BATTERMANN in *Astr. Nachr.*, No. 2926), and hence the photographic values appear to have suffered considerably from systematic error, as the probable error of a co-ordinate derived from their internal agreement is only $\pm 0''.05$ as against the value $\pm 0''.14$ just found from the heliometer companions.

I have plotted the residuals given by Mr. JACOBY and have come to the same conclusion as he did as to their not showing any systematic error of the photographic position-angles. On the other hand, however, there appears to be a marked deviation in the distance results, as for the smaller distances from the central star, say under 1500″, the photographic values are almost without exception larger than the heliometer ones. And I should like to state that this is probably largely due to a systematic error in the heliometer method of measurement which makes the distances come out too small, and which Dr. GILL and myself have only recently traced to its source. When this is taken into account, as I propose to do shortly in a revision of the Yale *Pleiades* work, the accuracy of the photographic results will be still more apparent. It speaks not a little, meanwhile, for their reliability that they have not failed to show up this small but important inconsistency in the heliometer measures.

YALE UNIVERSITY OBSERVATORY,
May, 1892.

OBSERVATIONS OF THE SUN IN 1891 AND 1892.

BY MISS ROSE O'HALLORAN.*

With commendable zeal Miss ROSE O'HALLORAN of San Francisco has made observations of the sun spots on every favorable day since November, 1891. In the period of 152 days between November 1, 1891 and March 31, 1892, only 23 days were wholly cloudy; and during this time 70 maps of the solar surface were constructed. Forty-one distinct groups of spots were observed, 19 in the northern hemisphere and 22 in the southern. Bridges connecting different members of the group were very numerous and distributed in the two hemispheres in the same proportion as the spots. Isolated spots were very few. Only five spots were observed to be within 10° of the solar equator. A rapidly developing group of spots near the sun's western limb was observed and sketched on January [illegible]9. The return of this group was looked for on the eastern limb on February 3 and 4, and was first seen the afternoon of the 4th. This group was identical with the Great February Sun Spot Group; so that Miss O'HALLORAN was one of its very earliest observers, and possibly the earliest. It was followed closely until unfavorable weather prevented further observations. The observations were made with a 4⅛-inch BRASHEAR refractor, with powers of 50, 100 and 200.

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* Abstract by W. W. CAMPBELL of a paper presented to the Society June 11, 1892, by Miss O'HALLORAN.